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ABSTRACT

Scaffolding refers to a temporary support framework used during construction. Applied to teaching and learning it describes measures to support a learner to become confident and self-reliant in a subject. In a Web environment scaffolding features need to replace the instructor. This paper discusses an approach to Web-based scaffolding based on the cognitive apprenticeship and activity theories. It suggests a set of four scaffold types that have made the scaffolding-supported virtual interactive tutorial successful. A novel evaluation approach for virtual tutorials is presented that is embedded into an iterative, evolutionary instructional design. (Contains 11 references.) (Author)

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An Evaluation of Scaffolding for Virtual Interactive Tutorials

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Abstract: Scaffolding refers to a temporary support framework used during construction. Applied to teaching and learning it describes measures to support a learner to become confident and self-reliant in a subject. In a Web environment scaffolding features need to replace the instructor. We discuss our approach to Web-based scaffolding based on the cognitive apprenticeship and activity theories. We suggest a set of four scaffold types that have made our scaffolding-supported virtual interactive tutorial successful. We present a novel evaluation approach for virtual tutorials that is embedded into an iterative, evolutionary instructional design.

Scaffolding

In increasingly knowledge-based societies, flexible and self-reliant learning becomes more and more important. Internet technologies make learning environments available without restrictions in time and location. However, the reduced direct contact between the instructor and the learner requires additional support. The term scaffolding refers to a temporary support framework that is used in the construction of buildings. Scaffolding is needed in the construction process, but will be removed once the building process is advanced and the building supports itself. Scaffolding has been suggested – the idea can be traced back to (Vygotsky 1978) – as an approach to support learners in their learning effort. The essential objectives are self-reliant learning and the achievement of competency in a domain. Scaffolding is in particular suitable to support active learning approaches. Classically, scaffolding refers to the support learners get from interaction with experts, teachers, and peers, see (Guzdial & Kehoe 1998) or (Suthers 1998). It should enable the learner to accomplish a task in a self-reliant way. The forms of support that can be provided include learning material, feedback, assessment, and demonstration. Three characteristics are essential for scaffolding:

- Modelling: the desired learning behaviour is modelled by providing an adequate learning (infra)structure.
- Support: Targeted support is given to the learner so that the learner can perform a task independently.
- Fading: Over time the support is reduced to let a learner become self-reliant.

The presentation by the instructor needs to be contextualised for the learner. The progress of the learner through the material needs to be coached. Fading of support is an integral part of scaffolding. We can distinguish two dimensions: fading provision of support and fading usage of support. Reflection and, if possible, the articulation of reflection should be encouraged.

Scaffolding is often considered as a part of the cognitive apprenticeship theory, see (Shabo, Guzdial & Stasko 1997) or (McLoughlin, Winnips & Oliver 2000). This theory addresses the problem of coaching a student to perform a specific task. A student learns through active participation in a task in an authentic setting in a close collaboration with a master. The master provides the scaffolding. The process of apprenticeship-oriented learning is characterised by increasing control and ownership by the learner. The cognitive apprenticeship theory puts an emphasis on reflection. A first phase of learning is typically coached, followed by reflection. In the final phase, free and self-reliant learning is supposed to take over. An authentic setting is another key element of a successful apprenticeship model. Its allows a learner to train with or within the subject of concern itself.

In the presence of computer-supported teaching and learning, the notion of scaffolding needs to be adjusted. In particular the World-Wide Web offers new ways for the learner to interact with the environment. The instructor's role in providing the scaffolding support can be taken over by an intelligent software agent. This new context allows innovative forms of support, but there is also the difficulty is to capture the usually verbal communication process between an instructor and a learner in a virtual setting. Elements of the coaching process

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have to be represented using Web technology. The student progress has to be measured against an expert model. However, the establishment of a successful expert model in the Web context is a problem, since often no topic-specific expertise for learning with the Web exists. The integration of the evaluation of learning and instructional design is therefore imperative. An evolutionary approach to the design of Web courseware in general and scaffolding in particular is needed.

Scaffolding is suitable for active learning. The instructor can be replaced by an intelligent agent that also controls the learner activity. Activity theory is a framework that can help us to redefine scaffolding in the context of the Web. Activity theory is a conceptual framework that can describe the structure, development, and context of computer-supported activities, (Nardi 1997). Its emphasis on the interaction between agents and their environments explains the principle of tool mediation. Tools shape the way humans interact with reality. Tools reflect experiences other people – such as the master in the apprenticeship approach – have made in trying to address similar problems. This experience is accumulated in structural and behavioural properties of the tool. A teaching and learning environment is the tool that provides a student with access to a part of the reality – the course subject – guided by structural and behavioural rules defined by the instructor. Approaches such as problem-based learning, constructivism, or exploratory learning can be derived from constructivist theory, (Dede 1995). Constructivism says that knowledge is constructed by a student, rather than taught to the student. The process of knowledge construction is viewed as deeper than the traditional approach. The student is engaged in solving meaningful problems – we call this active learning. This lends itself to be supported by scaffolding. Interactive educational systems can enable active, apprenticeship-based learning in a constructivist style.

Our objective here is to evaluate the impact of scaffolding on student learning in a virtual interactive tutorial environment that supports the autonomous learner. We will address aspects relating to the acceptance of scaffolding measures, the student behaviour in the presence of scaffolding, and the student performance in an evaluation of our own virtual tutorial. The questions of acceptance and effectiveness of scaffolding shall be answered in this paper. This evaluation is formative in nature. Since learning with Web technologies is not fully understood, an evolutionary approach feeding evaluation results back into the instructional design process is necessary.

A Virtual Tutorial

The School of Computer Applications at Dublin City University delivers its undergraduate Database course as a virtual course using Web technologies, (Pahl 2001). A central element is a virtual *tutorial service* that adds a dynamic, interactive dimension to the system, see Fig. 1. The tutorial service facilitates programming in the database language SQL. The service also facilitates learning about the activity of programming. It guides the student through a series of problems with increasing complexity. The central learning focus is on skills, but background knowledge is also required. The learning style can be both structured and unstructured.

The tutorial service offers the student to practice programming skills. A student can type in his/her attempt to formulate a query in the database language SQL and submit the query for execution to remote database server. The server reply will update the current page. In addition to the tutorial, a separate programming interface provides practical material beyond the examples used in the tutorial. This system also allows students to create and query their own databases. The idea behind this service is to support a more unstructured style of learning.

The tutorial is implemented based on a guided tour approach. It starts with a simple example and substantial scaffolding and increases the complexity of the problem and reduces the scaffolding features towards the end of the tutorial. The objective is to implement the apprenticeship model in an authentic setting. The three key aspects of scaffolding are addressed in the design of the tutorial:

- Modelling: The provided structure models the most suitable form of learning and guides the learning process.
- Support: Support in form of context pointers to background material and additional textual advice is provided. This form of coaching is necessary until the students can perform the tasks on their own.
- Fading: The support given through the tutorial is gradually reduced towards the end.

We have used several software-based scaffold types that substitute the interaction with the instructor in our virtual tutorial. Firstly, a guided learning process allows the learner to progress in a structured fashion based on an expert model towards self-reliance. Secondly, assessment and correction features provide necessary feedback and criticism. The system offers individual feedback in form of a check-function. These features are essential to reduce the scope for failure and allow the learner to assess his/her current level of competence. Thirdly, context

pointers to background resources contextualise the active elements. Key background resources are audio-visual lecture notes. Finally, comments that resemble advice given by an instructor in a face-to-face coaching process enable the learners to accomplish tasks that they would not be able to achieve on their own. We consider these four scaffolds types as essential in Web environments with little direct contact between instructor and learner. The combination of these types of scaffolds can ensure that the learner is provided with an environment that he/she can interact with in order to accomplish the learning objective. These features provide support for the autonomous learner in the process of becoming self-reliant.

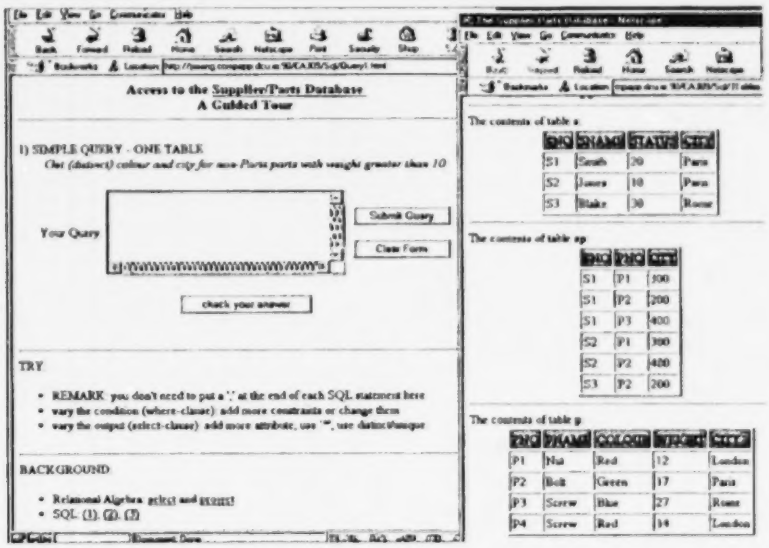

Figure 1: A Virtual Tutorial

The current implementation of the scaffolds is, however, the result of several years of evolution. Initially based on hypotheses about student learning and student behaviour, feedback from students and interactions with them have substantially influenced the design and implementation of the current scaffolding. Input that has been given to students face-to-face in a traditional delivery of the course is now reflected by features of the tutorial system. In particular the most appropriate learning path has been determined incrementally.

Articulation and reflection are often considered as critical elements in the learning process. Our system is based on two forms of usage. Firstly, a structured approach to learning during term in which students follow the guided tour and work on exercises. Secondly, an unstructured approach where students revise for their exams, re-address aspects that remained unclear before, etc. In-between these two forms of using the system, an implicit reflection phase is present. The students need to assess their current knowledge and skills before starting their exam preparation. A usage evaluation shows a clear distinction between the two forms of usage. In the first usage phase, a clear structure and a prescribed learning process is of advantage for most of the students. Once their skills and knowledge increases, students can determine their own individual needs and most suitable learning processes.

Evaluation Techniques

Acceptance and effectiveness are two key criteria for this formative evaluation of scaffolding. Our data is based on student surveys addressing the student perception, exam results addressing student performance, and Web mining addressing the student learning behaviour. A requirement is that the behaviour evaluation technique captures the essential student activities in relation to the scaffolding types discussed in the previous section. Background resources are linked to the tutorial material, i.e. context is constructed. Links to assessment and correction functions are implemented. The guided tour is implemented as a hypermedia system with suitable

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navigation support. The navigation behaviour of students within the Web system is the central element of behaviour evaluation.

Web mining is our central evaluation technique. Web mining is the application of data mining to the Web environment. We will use Web mining to evaluate the student behaviour in our virtual tutorial. This will be based on standard Web and data mining techniques (Agrawal & Srikant 1995). However, educational systems differ from commercial systems and students differ from visitors of a commercial Web site (Zaiane & Luo 2001). The student's goal – learning – is a long-termed one. Students usually spent a relatively long time in the system, and they will repeatedly visit the site. Adequate mechanisms need to be in place to support the teacher in developing and evaluating these complex behavioural patterns. The process of learning has to be described and analysed. For this purpose we have developed our own analysis software, which goes beyond standard Web mining technology.

Data mining is defined as the discovery and extraction of information from a database. Web mining is data mining for the Web, i.e. data available in Web-based systems is analysed. The database is here the access log generated by a Web server. Each entry usually contains the user (requester), the date/time of the request and the requested document. In our case of dynamically created pages, the classical problem with Web logs – pages are cached and therefore repeated accesses are not logged – does not apply. The following techniques can contribute to the evaluation of educational systems:

- Session statistics. The Web log is partitioned into sessions for each user. For each session, overall length in terms of time and number of pages visited are available. The average lengths of sessions help us to assess the investment of time for learning activities.
- Session patterns. Session patterns describe the behaviour of students in a session. This includes the sequence of pages that has been visited, whether elements have been repeated, etc. Important is the intertwined use of content and support elements. Their co-occurrence is an indicator of the acceptance of scaffolding.
- Time series of session data. The development of session statistics and also session patterns over time is particularly important. The change of any behaviour in relation to scaffolding features is central since fading use of support indicates the increasing self-reliance of the student. The variance in use over time is central to the determination of the effectiveness of scaffolding.

The increasing self-reliance, which in turn shows the effectiveness of the scaffolding approach, and the success and the learner's competency in the subject measured by exam results and exam/usage correlations have to be shown. A high usage at the beginning shows the acceptance and a considerable usage over time indicates the usability of the scaffolding features.

Evaluation Results

The methods of evaluation address the aspects learning behaviour, student opinion, and student performance. Learning behaviour analysis is based on automatically generated Web server statistics. The Web server statistics are based on data about Web page requests. Database and scaffolding requests for the tutorial have been analysed using this mechanism. Student opinion analysis is based on student questionnaires that survey the student perception. Student performance analysis is based on exam, project and continuous assessment results.

Two observations result from the statistical Web log analysis. Firstly, the data shows that the interactive tutorial is mainly (about 2/3) used during the semester to support students in their coursework and to a lesser extent (about 1/3) for the final exam preparation. Secondly, the programming interface of the tutorial is used in combination with the scaffolding features. This fact is confirmed by the session pattern analysis. This technique shows that a significant number of students use scaffolding features and follow scaffolding links from the tutorial. Web mining can give us a clear picture about the purpose of use. It allows us to identify individual learning sessions and determine the purpose of the sessions. A pattern analysis identifies sequential request patterns and associates them based on structure and content to a purpose.

The survey shows that the students recognise the potential of virtual courses to use different forms of learning at the same time. The interactive tutorial is used in combination with other resources provided by scaffolding. Web mining confirms that in 77% of all tutorial sessions students have also used online course notes at the same time. The students have looked up background material to solve specific problems interactively using the provided navigation support. While nearly all students avail of this feature in their first tutorial

sessions, we observed a decrease of scaffold usage during tutorials over time, indicating the increased knowledge and skills of students. The process of becoming self-reliant usually starts with a phase of structured, coached learning, followed by reflection and then more unstructured, self-determined learning. We found strong evidence for this behaviour.

In order to understand how students learn and how they use the support features offered, we need to look at the concrete behaviour. We need to look at how students navigate, whether they repeat units, whether they combine tutorial elements with scaffolds. A pattern analysis can answer these questions.

Tut1;[ExecQuery|Scaffold];Tut2; [ExecQuery|Scaffold]*; . . . ;Tut12;[ExecQuery|Scaffold]**

This is a behavioural pattern describing the intended learning path in our interactive tutorial service. This service consists of twelve tutorial units (*Tut1*, ... , *Tut12*) to be worked on sequentially. Within each unit students can iteratively (*) either execute an SQL query (*ExecQuery*) or use any of the scaffolding features (*Scaffold*). Web mining shows that 84% of all sessions actually follow this pattern of mixing interactive and scaffolding material – most of those that do not are either very short or use a different order.

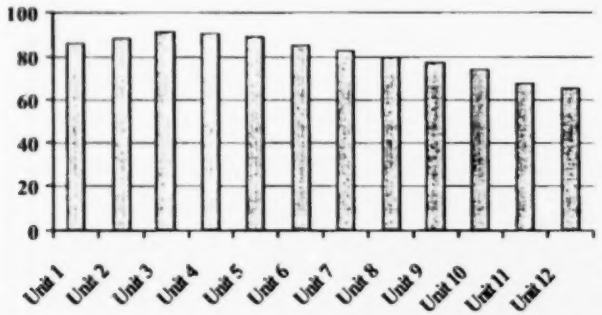

Figure 2: Support of Scaffolding Usage in percent

Fading – the reducing provision and usage of scaffolding features over time – is central in scaffolding. We have analysed time series of Web statistics and behavioural patterns to determine the success in this aspect. Fig. 2 shows the support of scaffolding usage, i.e. the fraction of students that use any scaffolding features in a session, in the twelve tutorial units. It shows that scaffolding features are used extensively by a large part of the student population in all tutorial units. In combination with Fig. 3 – which shows the decreasing length of sessions for the tutorials – and the fact that less scaffolding is provided in later units, it shows that effectively less time and less support is needed for the advanced tutorial units than for the earlier ones. The absolute numbers of scaffold requests have been reduced to around 35% in the later units compared to the first four units.

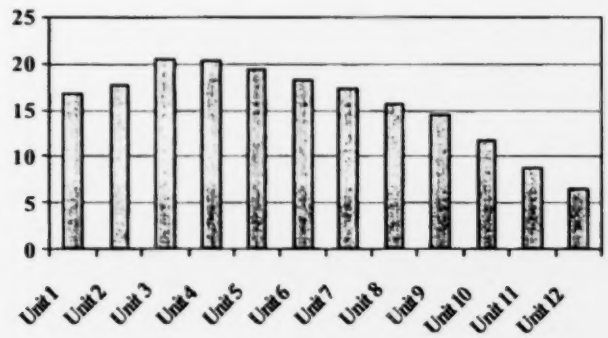

Figure 3: Average Length of Sessions in Number of Requests

We have surveyed the student opinion with respect to the usability of the system and the adequacy of the scaffolding approach. The students have pointed out that guidance and in particular the feedback features are central for a successful learning experience, i.e. scaffolding is considered necessary.

Performance is a key indicator for the effectiveness. Over the past couple of years we have constantly improved the scaffolding features of our interactive tutorial. Over the same period we have observed a steady improvement of exam and continuous assessment results.

Discussion and Conclusions

Virtual course technology offers the opportunity of using a course for lifelong learning approaches or distance access to courses. Distance education will play a major role in future education. In order to make an undergraduate course suitable for distance delivery, major functions of a teacher or coach have to be replaced by virtual system functions if direct contact is not possible. Scaffolding is an approach to provide features that can provide the learner with the necessary support. We have implemented a virtual tutorial with scaffolding for the database language SQL – a subject with a reasonable level and complexity of skills and knowledge. The tutorial is anchored in an authentic setting – which has been easy to realise for learning of programming skills. An important feature is that not only knowledge retention is the objective, but also the transfer of knowledge and skills to new application areas.

Our experience suggests that virtual tutorials can substitute the classical instructor-student interaction if sufficient guidance and integration is offered by the system. The interactive services have been accepted by students as a suitable tool in their preparation for continuous assessments, projects and exams. Our main result is that scaffolding can be successfully implemented for a Web-based course if the four scaffold types – guided learning process, assessment and correction, context pointers, advice – are provided. We have shown the success of the approach through the use of a novel evaluation technique – essentially Web mining – to determine the acceptance and the effectiveness of the approach. Guidance of the learning process is the key issue. Contextualised assistance of the learner is necessary to accomplish independence and self-reliance. A key concern is always the cost-effectiveness of a new technology. In our system, the investment into scaffolding features has been reasonable – the key problem was to get it right. This has required an incremental, evolutionary approach to the design and implementation of scaffolding. Our result is different from (Winnips, Collis & Moonen 2000), who have concluded with a more sceptical view on scaffolding. Our context and objective is to make virtual course delivery work. An improvement of classical delivery by Web-based features – as in their case – is not an option for us.

The Web as an open and flexible platform enhances the applicability of scaffolding features. The Web typically encourages students to explore a topic beyond the boundaries of given material. This supports the pro-active and exploratory nature of learning and allows the student to become self-reliant. Ultimately, to make scaffolding most effective, personalised and adaptive systems are the best solution. The needs and behaviour of individual students need to be considered in the provision of scaffolding. A user model needs to be built and student tracking is another prerequisite for adaptive personalised scaffolding. In most approaches to scaffolding, peer-communication and collaboration are central. Computer-supported systems usually offer shared workspaces. We have not considered this aspect since our course is set up to support autonomous learners.

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